Prune disease management

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Brown rot of Prune

Monilinia laxa &
M. fructicola

Blossom blight

Preharvest fruit decay
Disease cycle of *Monilinia fructicola* on prune and preharvest control measures
- The Disease Triangle of Plant Pathology -

**Host**
- Varietal susceptibility
- Planting design

**Pathogen**
- M. fructicola, M. laxa
- Inoculum potential (overwintering mummies, twig cankers)

**Environment**
- Wetness - rainfall, irrigation
- Temperatures above 58F

The interactions between the components effect the amount of disease.
Disease cycle of *Monilinia fructicola* on prune and preharvest control measures

- **Bloom sprays**
- **Preharvest sprays**
- **Orchard sanitation**
- **Twig Cankers**
- **Blossom blight**
- **Overwintering mummy on tree**
- **Conidia**
- **Ascus and ascospores**
- **Apothecia**
- **Rotten fruit on ground**
- **Twig blight and fruit rot**

???
Orchard sanitation
Removal of overwintering fruit mummies

Mummies and cankers as primary inoculum sources in the spring.
Dried Plum (prune) blossoms are susceptible at white tip through full bloom because all blossom tissues (green scales, petals, stamens, pistils) are susceptible and infection may lead to blossom blight, but the stamen and pistil tissues are the most susceptible.
EFFICACY AND TIMING OF FUNGICIDES, BACTERICIDES, AND BIOLOGICALS FOR DECIDUOUS TREE FRUIT, NUT, STRAWBERRY, AND VINE CROPS

2009

ALMOND
APPLE AND PEAR
APRICOT
CHERRY
GRAPE
KWIFRUIT

PEACH
PISTACHIO
PLUM
PRUNE
STRAWBERRY
WALNUT

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www.uckac.edu/plantpath

Statewide IPM Program
www.ipm.ucdavis.edu

Efficacy tables will be updated again for 2010
Fungicides Registered and in Development for Managing Prune Diseases

**Single-fungicides - Inorganics and Conventional Synthetics**

- **Inorganics**
  - Copper, Sulfur (M1) - 1960s
  - Ziram, (Maneb) (M2) - 1940s
  - Captan (M3) - 1950s
  - Bravo, Echo, Equus (M4) - 1960s

- **Dithiocarbamates**
  - Botran (M14) - 1960s

- **Phthalimides**
  - Elevate

- **Sterol inhibitors (SBIs)**
  - Elite**, Indar, Inspire, Orbit/Bumper, Rally, Quash**

- **Isophthalonitriles**
  - Luna Privilege*

- **Dicarboximides**
  - Rovral, Iprodione, Nevada (1980s)

- **Benzimidazoles**
  - Topsin-M, T-Methyl (1970s)

- **Anilinopyrimidines**
  - Vangard, Scala

- **Aromatic Hydrocarbon**
  - Botran (M14) - 1960s

**New 2009/10:**
- Elite**, Inspire, Quash**, Luna Privilege*

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* - Not planned for registration as a single AI.  ** - For fresh prune only.
Fungicides Registered and in Development for Managing Prune Diseases

Conventional Synthetic Fungicides – Pre-mixtures

- **Pristine** 7+11 2000s
- **Adament*** 3+11 2000s
- **Distinguish** 9+11 *New: 2000s*
- **Inspire XT** 3+3 *New: 2010s*
- **Inspire Super** 3+9 *New: 2010s*
- **Luna Sensation** 7+11 *New: 2010s*
- **Quilt Xcel** 3+11 *New: 2010s*
- **Quadris Top** 3+11 *New: 2010s*

New: 2010s

- 3 SBIs
- 7 SDHIs
- 9 Anilinopyrimidines
- 11 Qols

* - For fresh prune only. ** - For prune, CA registration pending.

Natural Products

- **Regalia,** **Actinovate,** **Cerebrocide**

Natural products from plant extracts that potentially will be OMRI approved were evaluated for organic farming of almonds.
Pre- and post-infection treatments with selected fungicides - Blossom blight of French prune -

### Pre-infection activity

<table>
<thead>
<tr>
<th></th>
<th>Full bloom application, inoculation with <em>M. laxa</em> after 24 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>S</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Quash 50WG 2.5 oz</td>
<td>bc</td>
</tr>
<tr>
<td>Inspire 2.08EC 7 fl oz</td>
<td>c</td>
</tr>
<tr>
<td>Inspire Super SC 20 fl oz</td>
<td>bc</td>
</tr>
<tr>
<td>Adament 50WG 4 oz</td>
<td>bc</td>
</tr>
<tr>
<td>Distinguish 480SC 12.8 fl oz</td>
<td>b</td>
</tr>
<tr>
<td>Luna Sensation SC 5 fl oz</td>
<td>bc</td>
</tr>
<tr>
<td>Quadris Top 10 fl oz</td>
<td>bc</td>
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</table>

### Post-infection activity

<table>
<thead>
<tr>
<th></th>
<th>Inoculation, treatment after 24 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>S</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Scala 600SC 12.5 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Vangard 75WG 5 oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Quash 2DC 5 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Luna Privilege 4 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>PM</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Adament 50WG 6 oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Inspire Super 10 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Luna Sensation 4 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Quadris Top 14 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Quilt Xcel 10 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Inspire XT 7 fl oz</td>
<td><img src="image" alt="Graph" /></td>
</tr>
</tbody>
</table>
Summary:
Fungicides for blossom blight control

Highly effective (+++ or ++++) for blossom blight, pre- and post-infection activity:

- **Registered:**
  - SBIs (3): Orbit/Bumper, Indar, Elite (fresh prune only)
  - Anilinopyrimidines (AP) (9): Vangard, Scala
  - Dicarboximides (2): Rovral (-oil)/Nevado/Iprodione
  - Hydroxyanilide (17): Elevate
  - Pre-mixtures: Pristine(7/11), Adament (3/11) (fresh prune)

- **Planned Registrations:**
  - SBIs (3): Quash (currently for fresh, expand to dried), Inspire
  - SDHIs (7): Luna Privilege (?)
  - Pre-mixtures: Inspire Super (3/9), Inspire XT (3/3), Luna Sensation (7/11), Quadris Top (3/11), Quilt Xcel (3/11),…
Blossom blight control with fungicides

UC guidelines
2 applications during bloom
Use when environmental conditions are highly conducive (rain)

Delayed bloom application
1 application at 30-50% bloom
Use when environmental conditions are less favorable
In previous years’ pre-infection experiments, the activity of biologicals and natural products was low.
Management of brown rot fruit decay with preharvest fungicide treatments
Efficacy of 14-day PHI fungicide field treatments on the incidence of brown rot after wound inoculation

Treatments were applied in the field using an air-blast sprayer calibrated for 100 gal/A. Omni Supreme spray oil was used at 2% in all treatments. After harvest inoculated fruit were incubated for 7 days at 20C.
7-day PHI fungicide treatments for management of brown rot decay of French prune – Yuba-Sutter Co. 2009

Treatments were applied in the field on 8-4-09 using an air-blast sprayer (100 gal/A). Omni Supreme Spray oil was used. After harvest, fruit were either spray- or wound-inoculated with conidia of M. fructicola (30,000 conidia/ml). Fruit were then incubated for 7 days at 20 C.
Efficacy of high- and low-gallonage fungicide field treatments to clustered and exposed fruit on the incidence of brown rot after inoculation.

Treatments were applied on 8-14 and 8-28. All fruit were inoculated on the inside surface opposite to the perimeter.
**14- and 0-day PHI treatments with natural products for management of brown rot decay of French prune - UC Davis 2009**

- Evaluation of application volumes in preventing decay of exposed fruit and fruit inside clusters -

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Application volume/A</th>
<th>Exposed fruit</th>
<th>Fruit inside clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>---</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Orbit 3.6EC 4 fl oz - Oil 1.5%</td>
<td>80 gal</td>
<td>bc</td>
<td>bc</td>
</tr>
<tr>
<td>Orbit 3.6EC 4 fl oz - Oil 1.5%</td>
<td>160 gal</td>
<td>de</td>
<td>c</td>
</tr>
<tr>
<td>Quash 50WG 3.5 oz - Oil 1.5%</td>
<td>80 gal</td>
<td>de</td>
<td>cd</td>
</tr>
<tr>
<td>Quash 50WG 3.5 oz - Oil 1.5%</td>
<td>160 gal</td>
<td>e</td>
<td>d</td>
</tr>
<tr>
<td>Pristine 38WG 14.5 oz - Oil 1.5%</td>
<td>80 gal</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>Pristine 38WG 14.5 oz - Oil 1.5%</td>
<td>160 gal</td>
<td>b</td>
<td>bc</td>
</tr>
<tr>
<td>Luna Sensation 7 fl oz - Oil 1.5%</td>
<td>80 gal</td>
<td>cd</td>
<td>b</td>
</tr>
<tr>
<td>Luna Sensation 7 fl oz - Oil 1.5%</td>
<td>160 gal</td>
<td>cd</td>
<td>cd</td>
</tr>
<tr>
<td>Quadris Top 14 fl oz - Oil 1.5%</td>
<td>80 gal</td>
<td>cd</td>
<td>b</td>
</tr>
<tr>
<td>Quadris Top 14 fl oz - Oil 1.5%</td>
<td>160 gal</td>
<td>bc</td>
<td>b</td>
</tr>
</tbody>
</table>

Treatments were applied in the field on 8-14 and 8-28-09 using an air-blast sprayer at 80 or 160 gal/A. Omni Supreme Spray oil was used. At harvest, either single fruit from the tree perimeter (exposed fruit) or fruit from clusters were collected and wound-inoculated with conidia of *M. fructicola* (30,000 conidia/ml) on the unexposed side of the fruit. Fruit from inside clusters were inoculated on the inside facing side.
Summary: Fungicides for fruit brown rot control

- All fungicides significantly reduced the incidence of brown rot decay on harvested fruit after non-wound inoculation with *M. fructicola*.

- When fruit were wound-inoculated after treatment and harvest, the efficacy of most treatments was reduced as compared to the non-wound inoculations (fungicides are contact materials).

- The addition of a spray oil in general significantly increased the efficacy of the fungicides (comparative research in 2007-08).

- Biologicals and natural products were ineffective as protective treatments of fruit (research done in 2007-08).

- Application at 160 gal (as compared to 80 gal) was beneficial for protecting fruit outside and inside clusters from brown rot for some fungicides.
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<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Resistance risk</th>
<th>FRAC No.</th>
<th>Brown Rot Blossom</th>
<th>Brown Rot Fruit</th>
<th>Russet scab</th>
<th>Rust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benlate</td>
<td>high</td>
<td>1</td>
<td>++++</td>
<td>++++</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Distinguish (Reg. but not marketed)</td>
<td>medium</td>
<td>9/11</td>
<td>++++</td>
<td>++++</td>
<td>--</td>
<td>++</td>
</tr>
<tr>
<td>Orbit, Bumper</td>
<td>high</td>
<td>3</td>
<td>++++</td>
<td>++++</td>
<td>--</td>
<td>+++</td>
</tr>
<tr>
<td>Elite (Fresh prune)</td>
<td>high</td>
<td>3</td>
<td>++++</td>
<td>++++</td>
<td>--</td>
<td>+++</td>
</tr>
<tr>
<td>Indar</td>
<td>high</td>
<td>3</td>
<td>++++</td>
<td>++++</td>
<td>--</td>
<td>+++</td>
</tr>
<tr>
<td>Adament (Fresh prune)</td>
<td>medium</td>
<td>3/11</td>
<td>++++</td>
<td>++++</td>
<td>--</td>
<td>+++</td>
</tr>
<tr>
<td>Pristine</td>
<td>medium</td>
<td>7/11</td>
<td>++++</td>
<td>++++</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Rovral/Iprodione/Nevado w/oil</td>
<td>low</td>
<td>2</td>
<td>++++</td>
<td>NR</td>
<td>--</td>
<td>NR</td>
</tr>
<tr>
<td>Scala</td>
<td>high</td>
<td>9</td>
<td>++++</td>
<td>6</td>
<td>--</td>
<td>ND</td>
</tr>
<tr>
<td>Topsin-M/T-Methyl w/oil</td>
<td>high</td>
<td>1</td>
<td>++++</td>
<td>++++</td>
<td>--</td>
<td>----</td>
</tr>
<tr>
<td>Vangard</td>
<td>high</td>
<td>9</td>
<td>++++</td>
<td>6</td>
<td>--</td>
<td>ND</td>
</tr>
<tr>
<td>Benlate</td>
<td>high</td>
<td>1</td>
<td>++++</td>
<td>+/-</td>
<td>--</td>
<td>----</td>
</tr>
<tr>
<td>Elevate</td>
<td>high</td>
<td>17</td>
<td>++++</td>
<td>++++</td>
<td>ND</td>
<td>----</td>
</tr>
<tr>
<td>Rovral/Iprodione/Nevado</td>
<td>low</td>
<td>2</td>
<td>++++</td>
<td>NR</td>
<td>--</td>
<td>NR</td>
</tr>
<tr>
<td>Topsin-M/T-Methyl</td>
<td>high</td>
<td>1</td>
<td>++++</td>
<td>+/-</td>
<td>--</td>
<td>----</td>
</tr>
<tr>
<td>Abound</td>
<td>high</td>
<td>11</td>
<td>++</td>
<td>+</td>
<td>--</td>
<td>+++</td>
</tr>
<tr>
<td>Botran</td>
<td>medium</td>
<td>M14</td>
<td>++</td>
<td>++</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Bravo/Chlorothalonil/Echo/Equus</td>
<td>low</td>
<td>M5</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>----</td>
</tr>
<tr>
<td>Captan</td>
<td>low</td>
<td>M4</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>----</td>
</tr>
<tr>
<td>Gem (Fresh prune)</td>
<td>high</td>
<td>11</td>
<td>++</td>
<td>+</td>
<td>--</td>
<td>+++</td>
</tr>
<tr>
<td>Rally</td>
<td>high</td>
<td>3</td>
<td>++</td>
<td>++</td>
<td>--</td>
<td>----</td>
</tr>
<tr>
<td>Sulfur</td>
<td>low</td>
<td>M2</td>
<td>+/-</td>
<td>+/-</td>
<td>--</td>
<td>++</td>
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</table>
# Fungicide treatment timing in prune (dried plum)

http://www.ipm.ucdavis.edu

<table>
<thead>
<tr>
<th>Disease</th>
<th>Green bud</th>
<th>White bud</th>
<th>Full bloom</th>
<th>May</th>
<th>June</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown rot&lt;sup&gt;a&lt;/sup&gt;</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>—</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Russet scab&lt;sup&gt;b&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>+++</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Rust&lt;sup&gt;c&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
</tbody>
</table>

Rating: +++ = most effective, ++ = moderately effective, + = least effective, and — = ineffective.

Timings used will depend upon orchard history of disease, length of bloom, and weather conditions each year.

- a. Flowers are susceptible beginning with the emergence of the sepals (green bud) until the petals fall, but are most susceptible when open.
- b. A physiological disorder, no pathogens involved.
- c. More severe when late spring rains occur.
Fungicide resistance in pathogens of prune
Evaluation of the in vitro toxicity of fungicides against *Monilinia* spp.

- Reported control failures after treatments with anilinopyrimidine (AP) and SBI fungicides.
- Resistance to AP fungicides in pathogens of other crops has been reported in CA.
- In 2007 we found AP resistance in one isolate of *M. fructicola* in one CA prune orchard (West Butte Co.).
- Resistance against SBI fungicides has developed in other stone fruit growing areas of the country.
- Fungal isolates obtained from decaying fruit in 2009 were evaluated for their in vitro sensitivities (central Butte Co.).
Quantification of fungicide sensitivity: The spiral gradient dilution method

Creating a radial, exponential gradient of a fungicide using a spiral plater

After a 2-4 h incubation period a continuous gradient is formed.

Brown rot resistance to AP fungicides in a California stone fruit orchard in 2009

• In Northern California:
  - AP resistance in the brown rot pathogen *M. fructicola* was detected in 2007.
  - AP resistance in the brown rot pathogen *M. laxa* was detected in 2009.
• All isolates were sensitive to propiconazole (Orbit) and Rovral

![Image of fungal growth on agar plate with labels for Cyprodinil, Lowest concentration, and Highest concentration]
In vitro toxicity of fungicides against *M. laxa* - 2009

- EC$_{50}$ values of 8 of the 9 isolates collected in an orchard with treatment failures increased by 10 to 30 times as compared to baseline sensitive wild-type isolates.

- These isolates were highly sensitive to SBI fungicides.
Summary: *In vitro toxicity of Monilinia spp. against selected fungicides*

- One isolate of *M. fructicola* resistant to cyprodinil was found in our limited 2007 survey.

- The majority of isolates of *M. laxa* collected from one location in 2009 was resistant to AP fungicides (e.g., cyprodinil, pyrimethanil).

- Thus, resistance development is occurring. If not managed with appropriate anti-resistance strategies, resistant isolates will likely continue to be selected for. This may result in widespread treatment failures and loss of an important fungicide class.

  - Limit AP fungicides to bloom treatments (ideally 1/yr)
  - Mix with other fungicides (e.g., captan, chlorothalonil)
Prune rust caused by *Tranzschelia discolor*

Early symptoms of disease will start in late April/early May. Defoliation may occur in July and August in severe years.

The incidence of rust was very low at most locations in 2007-2009 and our studies on this disease were postponed.
Components of an integrated disease management program for brown rot of stone fruit

- Early disease detection
- Planting
  - Variety selection (host resistance)
  - Plant spacing (greater air movement, shorter drying times)
- Cultural practices
  - Avoid high-angle sprinkler irrigation
  - Provide a balanced nutrition
  - Pruning practices (improved microclimate, removal of diseased tissue)
- Sanitation
  - At harvest remove all fruit from trees
  - Remove overwintering mummies from trees and cultivate mummies into soil
- Chemical control
Identification of Aspergillus species associated with dried plum fruit

- Two morphologically distinct species obtained in 2008 were identified based on morphological characteristics: *A. niger* and *A. chevalieri*.

- No new reports on fungal growth on dried plums in 2009.
- Molecular methods based on DNA sequence data are being developed for additional identification.
Factors affecting cultural characteristics include agar media, age, species variability, etc.
DNA sequence-based approach for identification of Aspergillus species

rDNA ITS 1 sequences were obtained from GenBank and the alignment was done using Clustal W.

Alignments are based on 3 isolates of Aspergillus chevalieri (teleomorph Eurotium intermedium), 3 isolates of A. glaucus (teleomorph E. herbariorum), 2 isolates of A. niger, 3 isolates of A. terreus, 3 isolates of A. fumigatus, 4 isolates of A. parasiticus, 3 isolates of A. flavus and 1 isolate of A. nidulans.

Highly variable DNA regions
DNA sequence-based approach for identification of *Aspergillus* species

- Molecular detection methods are being developed for species identification.
- Due to the high variability within the ribosomal DNA region a PCR-RFLP approach will be first pursued (easier to develop and less expensive)
  - Amplification of the rDNA region
  - Digest with restriction enzymes
  - Electrophoresis
- Alternatively or subsequently, species-specific primers will be developed for predominantly occurring species